9043 Status Report: Phase I, Final Report

31 August 1962

ABSTRACT

The new viewing equipment for the Image Enhancement Viewer has been installed and the system now operative with a ZOOM feature and magnifications of the aerial image possible out to 90x. A new 70mm film format provides simplified recording of the unmagnified aerial image, and a 35mm camera attachment to the binocular viewing system records the magnified image out to 36x. The study program to determine the feasibility of the rotating mechanical Gaussian filters showed the filters to be impractical due to the reflection or glint from the filter tip which lowered image contrast and masked all filtering effects. The collateral theoretical and experimental studies formulated image enhancement in terms of spatial filtering with the sharp cutoff, occluding filters, but requires more time for useful completion. Recommendation is made to continue work on the Image Enhancement Viewer in order to render it more useful to the contracting agency. Specific modifications to improve the equipment are suggested, with no increase in funding or extension of delivery schedule required. Completion of the theoretical and experimental studies is also recommended.

Approved For Release 2000/05/10 : CIA-RDP78B04747A003100010043-0

1. General Review

Phase I of this project consisted of two major efforts, one an engineering modification and instrument improvement program, the other a feasibility study. The former concerned itself with improvement of the viewing equipment of the Image Enhancement Viewer. The latter considered the possibility of frequency attenuation by means of mechanically rotating filters located in the plane of diffraction. Upon demonstration of feasibility, Phase II would incorporate these findings and replace the present filtering method with the newer types.

The letter reports submitted as per contract requirement detailed the progress in these two major areas. Progress in the theoretical aspects was also reported, and a definite analytical formulation of image enhancement was begun. A study of the performance of the occluding filters was undertaken, with the ultimate aim of a final performance evaluation. This latter study was specifically called for in the contract.

Phase I took approximately four months to complete, and a preliminary verbal report given to the contracting agency on 27 August 1962, at his facility. This present report constitutes the final, written report on Phase I activities.

2. Engineering Modifications to the Image Enhancement Viewer

In accordance with the proposal and contract statement, a ZOOM optical system was installed. This unit is a Bausch and Lomb

Tri-Ocular, permitting a more comfortable viewing arrangement than that previously employed. The eyepieces are 5x and 7.5x, and two objectives are provided on a three-unit nosepiece, one of 6x, the other of 2x. The system Zooms a factor of two, thereby giving the viewer a range of magnification of 10x to 90x. It was not practicable to provide a continuous Zoom magnification from 1 to 25 as previously intended, in view of the requisite multiple changing of objectives and eyepieces. A 35mm camera is coupled to the system, and the magnified image can be recorded. The power of this unit is 3x (simple field-flattening optics), so that the maximum magnification which can be achieved photographically is 36x.

An improved recording camera has been incorporated in the system. This is a 70mm Linhof Cine Rollex back especially adapted for the present use. Entry is provided through the back so that a microscope can be focussed on the focal plane (at 105x, nominal), and optimum placement of the aerial image on the recording film can be effected. Details of the Tri-ocular, 70mm film format, and the 35mm camera can be seen in Figure 1, a photograph of the viewing unit.

A Filar eyepiece (12.5x) is provided for one side of the binocular system and linear measurements can be made with this. The entire microscope body is mounted on a ring which contains azimuthal markings. As the microscope is rotated, angles may be read directly, and, with the aid of a vernier on the inner plate, known to one (1) angular minute. Thus, linear and angular measurements on the aerial image are now possible. These details are shown in Figure 2.

The optical constants of the Image Enhancement Viewer optical systems are detailed in Table I. This table lists all viewing optical

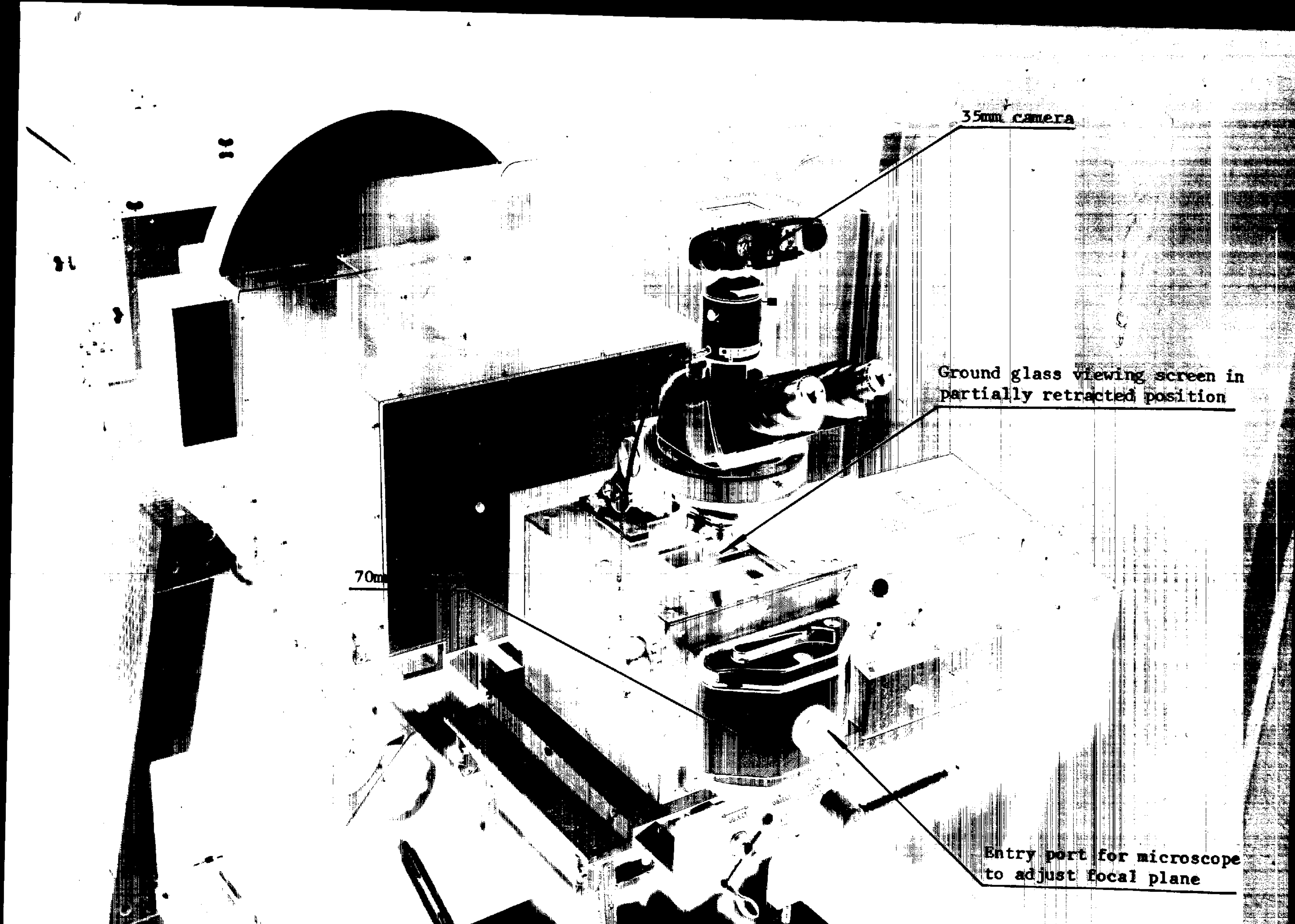


Figure [illegible] Photograph of the viewing [illegible] Image E[illegible] in the normal viewing posit[illegible] showing the en[illegible] modifications to the viewing equipment.

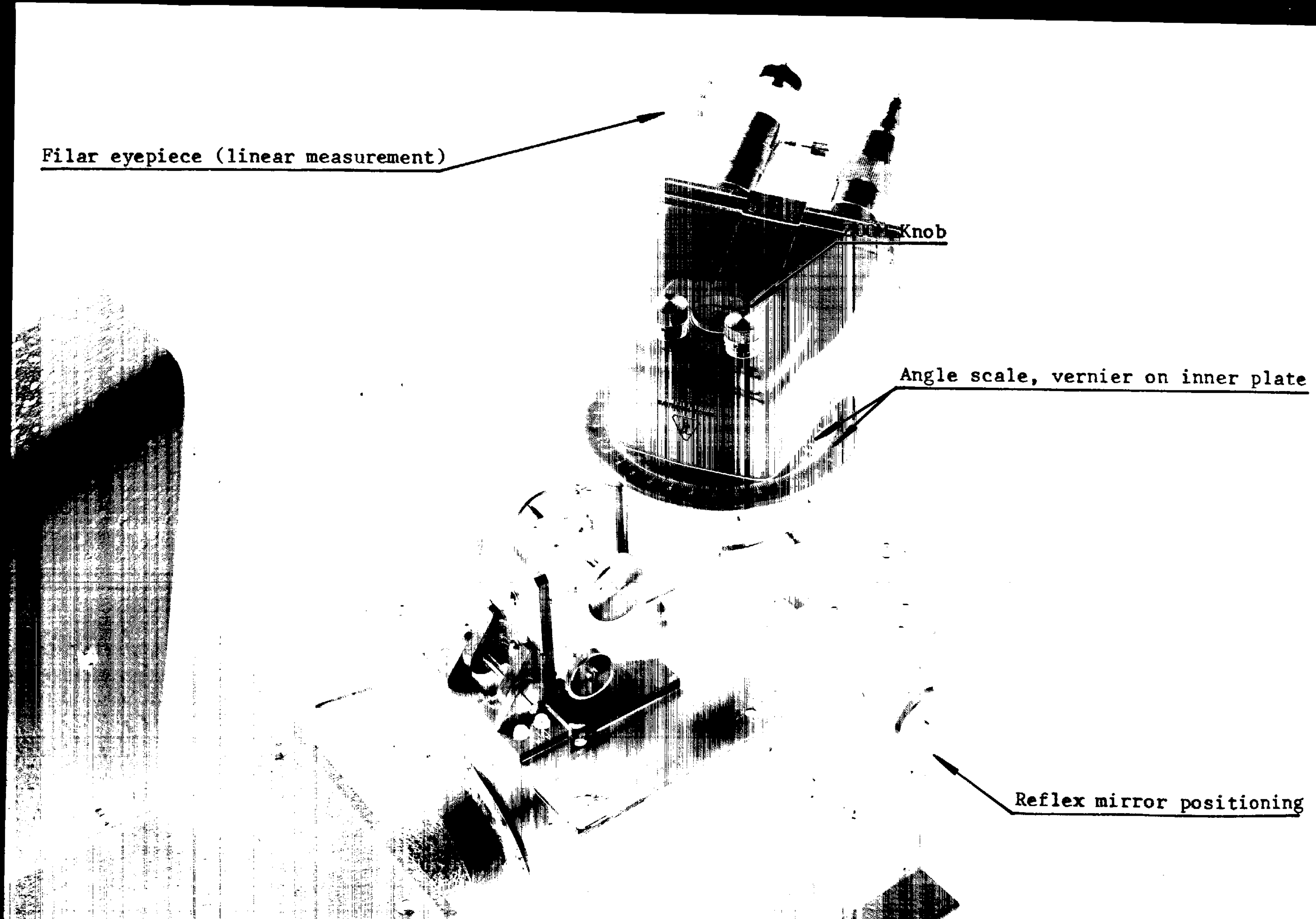


Figure 2: Photograph of the modifications showing the angular measurement scales and the method of linear measurement.

TABLE I

Summary of Optical System Constants

Main optical system magnification: 1.106 (measured)

Microscope objectives: 2x, 6x, 21x*

Eyepieces (binocular): 5x, 7.5x

Filar eyepiece : 12.5x

ZOOM Range : 2x

35mm Camera Field Flattener: 3x

(Measurement on Filar eyepiece can be made to 0.01mm on aerial image in eyepiece. Actual measurement must be obtained by reduction through total system magnification.)

The viewing system has continuously variable magnification, within four steps. Using the combinations of 2x and 6x objectives, together with the 5x and 7.5x eyepieces and the 2x ZOOM, the four steps are: 1) 10x - 20x, 2) 15x - 30x, 3) 30x - 60x, and 4) 45x - 90x. The following table summarizes the extremal magnifications available for the several viewing modes. To ascertain total magnification, the magnification indicated by the combination of objective, ZOOM setting and eyepiece (or camera) must be multiplied by the main optical system magnification.

Viewing Mode	Magnification Maximum	Magnification Minimum
Visual		
Through binoculars	90	10
Glass viewing screen	1	1
Measurement (filar)	150	25
Photographic		
70mm film format	1	1
35mm camera	36	6

* The 21x objective is used for adjusting the focal plane of the 70mm film format, and is not a part of the viewing system of the microscope.

elements and tabulates the extremal magnifications available with the instrument. The main optical system magnification has been determined experimentally and is also shown.

Photographic tests were made to establish the focal plane in the 70mm film format and to check the accuracy of the optical method of adjustment. The focus is correct out to the limit of the system. The photographic tests made on the 35mm camera indicate the maintenance of correct focus. As could be expected the exposure time required to record the magnified images is considerably larger than that for the 70mm film format, nominally at unity magnification. Since the numerical aperture of the objectives is larger than that of the main optical system (an F/8 cone), the theoretical loss in image intensity is proportional, to the square of the magnification (assuming no transmission losses in the optical elements). Thus, the "first-order" exposure increase for magnification of 6x and 36x would be 36 and 1296 respectively. Such increases would suggest the use of fast film. Since these photographic images will not be greatly enlarged for subsequent display and examination purposes, the grain problem ordinarily associated with fast films will not generally apply.

In addition to the viewing unit modifications, a new shutter was installed. This is a self-cocking type, adjustable from the outside of the Source Unit. It is tripped manually, at the Source Unit. Figure 3 contains a photograph of this unit and shows the significant features of the new arrangement.

As evident from Figures 1 and 2, the modifications have not been metal-finished. This was in anticipation of Phase II construction, so

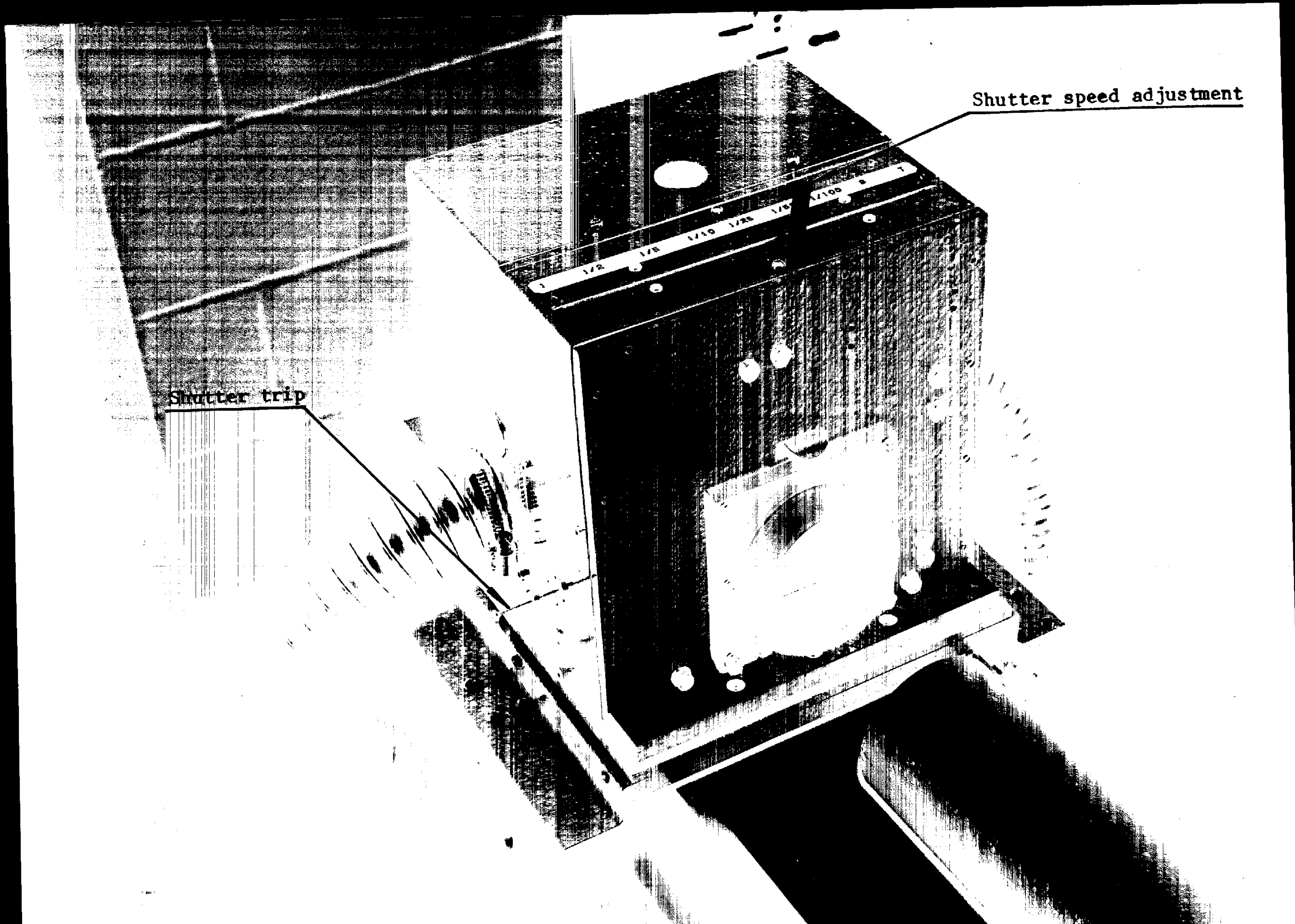


Figure 3: Photograph of the Source Unit showing the speed adjust[illegible]
and trip for the newly-installed shutter.

that all parts might be metal-finished compatibly. All instrument modifications called for under Phase I have now been completed, the system calibrated and fully operative.

3. Feasibility Studies of Rotating Spatial Filters.

Introduction:

Previous development studies had demonstrated the feasibility of frequency attenuating filters, and that such filters could be fabricated from photographic materials. These filters were found to be inadequate in quality due to the deviations in glass flatness which resulted in image deformation above 40 lines/mm. It was therefore decided that application of the rotating principles through which these filters were made would be the best approach, and would be free of the objectionable features of glass placed in the plane of diffraction. Preliminary to the installation and use of such filters was the establishment of feasibility for achieving a real filtration effect and for incorporation into a semi-automatic device for insertion and use of such filters in the Image Enhancement Viewer.

The preliminary investigation therefore had three major objectives; 1) a mathematical description of the transmission characteristics of a rotating, profiled slot, 2) assuming a Gaussian cross-section, a profiled contour specification and determination of means of fabrication, and 3) the provision of a means for rotation and optical alignment which would test the feasibility of such a filter system.

The Mathematics of the Rotating Filter:

The mathematical description of the transmission characteristics of a rotating, profiled slot follows from a consideration of Figure 4. The derivation assumes bilateral symmetry for the slot not only for mathematical convenience, but also because its mechanical realization will minimize vibration, when rotated, due to small machine imbalances.

Consider the transmission lying along a circle of radius, $\bar{r}$. The arc length in the portions of Figure 4 defined by the region of T_2 is denoted $S(\bar{r})$. Then the percentage of light (transmission) which passes through the filter at the given radius, while rotating, can be written

$$T(\bar{r}) = \frac{S(\bar{r})}{\pi \bar{r}} \left\{ \frac{\sqrt{T_2} - \sqrt{T_1}}{\sqrt{T_2}} \right\} + \frac{\sqrt{T_1}}{\sqrt{T_2}}.$$

in the case of amplitude weighting (coherent system illumination), or

$$T(\bar{r}) = \frac{S(\bar{r})}{\pi \bar{r}} \left\{ \frac{T_2 - T_1}{T_2} \right\} + \frac{T_1}{T_2}$$

in the case of intensity weighting (incoherent system illumination).

Now in the case of an opaque material through which the profiled slot has been cut, $T_1 = 0$, and $T_2 = 1$. If these values are substituted into the above equations, they reduce to the same result,

$$T(\vec{r}) = \frac{S(\bar{r})}{\pi \bar{r}} = \frac{\theta(\bar{r})}{\pi}.$$

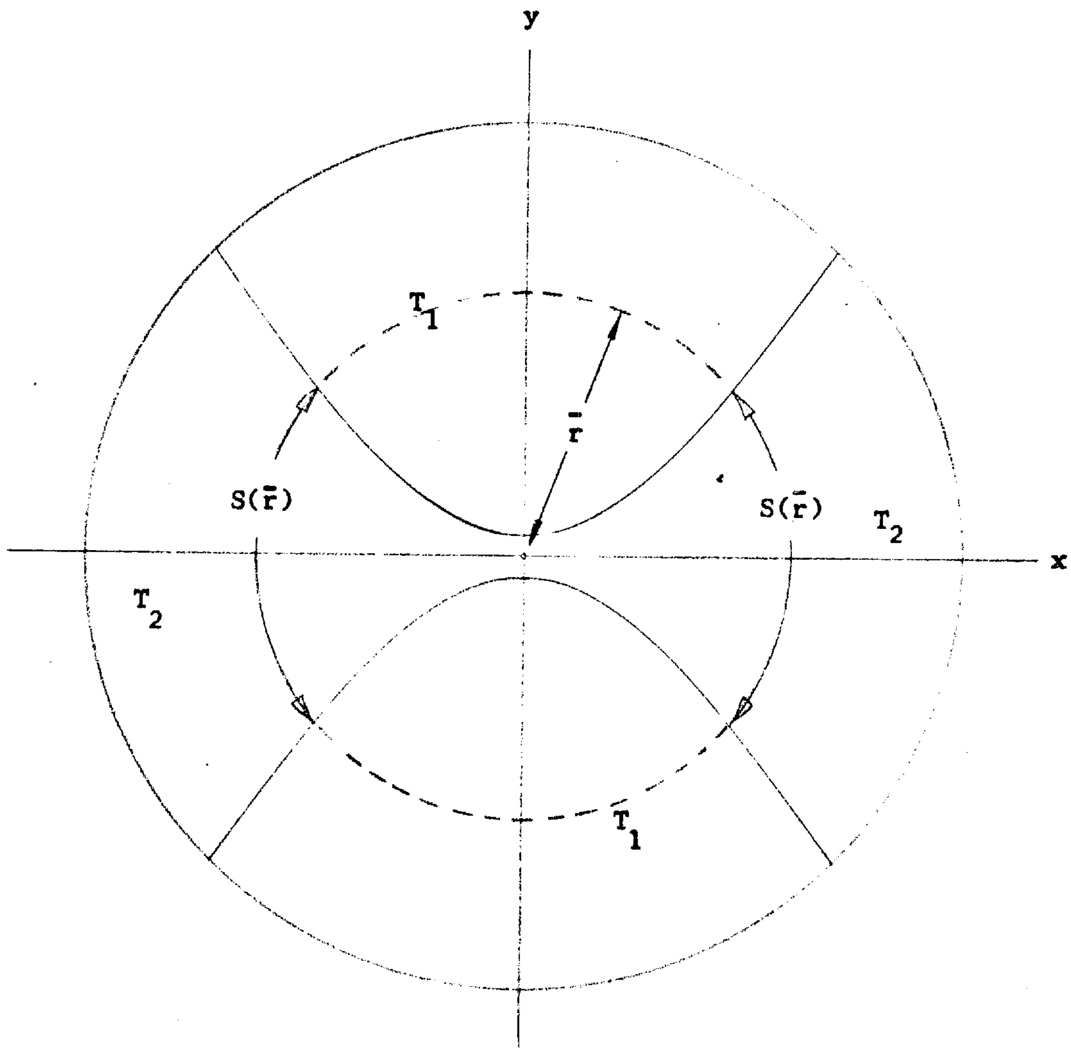


Figure 4: Diagram of a generalized slot contour. T_1 is taken to be smaller than T_2. The slot is assumed to be rotating sufficiently fast to eliminate flicker.

where $\theta(\bar{r})$ is the angular separation of the slot at a radius $\bar{r}$. This is now similar in form to the expression derived in the final report of the 9019 program (specifically, Section 3.1.3, Aperture Shape). Then only a specification of the angular spacing of the slot contour is required, and it will be valid under coherent or incoherent treatment provided the filter consists of clear and opaque sections.

It is now necessary to specify the required contour. Since it is desired to have the angular distribution as a function of the required transmission characteristics, the last equation must be transformed accordingly. Then,

$$\theta(\bar{r}) = \pi T(\bar{r}) \quad .$$

Specifications of $T(\bar{r})$ proceeds as in the 9019 Final Report, with one significant change. That report cited values of transmission which were defined for intensity-weighting. Since the plane in which the filters are to operate contains a distribution of amplitude and phase, the weighting must be on an amplitude basis. This can be accomplished mathematically by assuming the filter to introduce no more than a constant phase shift in frequency space* and taking the square root of the intensity-weighting transmission. Since this mathematical operation radically affects the analytical tractability of the integral equations governing the system imagery, the form of the filter has been changed somewhat from that developed for the 9019 program. Considered as an amplitude weighting function, the cross-

* In practice, since the slot will be composed of clear and opaque areas, this is not an assumption, because phase will be unaffected. It becomes an assumption in the case of a continuous distribution of density which has not been immersed or laminated between flats.

section of a Gaussian filter can be written

$$G(\bar{w}) = \psi_2^{1/2} - \left(\psi_2^{1/2} - \psi_1^{1/2}\right) e^{-\beta w^2}$$

where

ψ_2 = maximum transmission

ψ_1 = minimum transmission

β = filter crop-off coefficient

w = spatial frequency (radian)

Normalizing this function to the maximum value of spatial frequency passed by the optical system, and converting the frequency scale to a linear measurement, the desired angular contour relationship for the rotating Gaussian filter is given by

$$\theta(\bar{r}) = \pi\psi_2^{1/2} \left\{1 - \left(1 - \sqrt{\frac{\psi_1}{\psi_2}}\right) e^{-a\bar{r}^2}\right\}$$

where $\bar{r}$ varies from 0 to 1.0, and the equation represents the arc length defined in Figure 4. Application of the mathematical process defined in Section 2.6 of the 9019 final report (for ascertaining the optimum Gaussian filter constants) shows that equation (11) of that report changes to

$$\sqrt{\frac{\psi_1}{\psi_2}} = 1 - (\rho + 1)^{3/2} e^{-3\rho/2}$$

where $\rho = 4\beta c$, constants pertaining to input pulse and filter width. This is plotted in Figure 5.

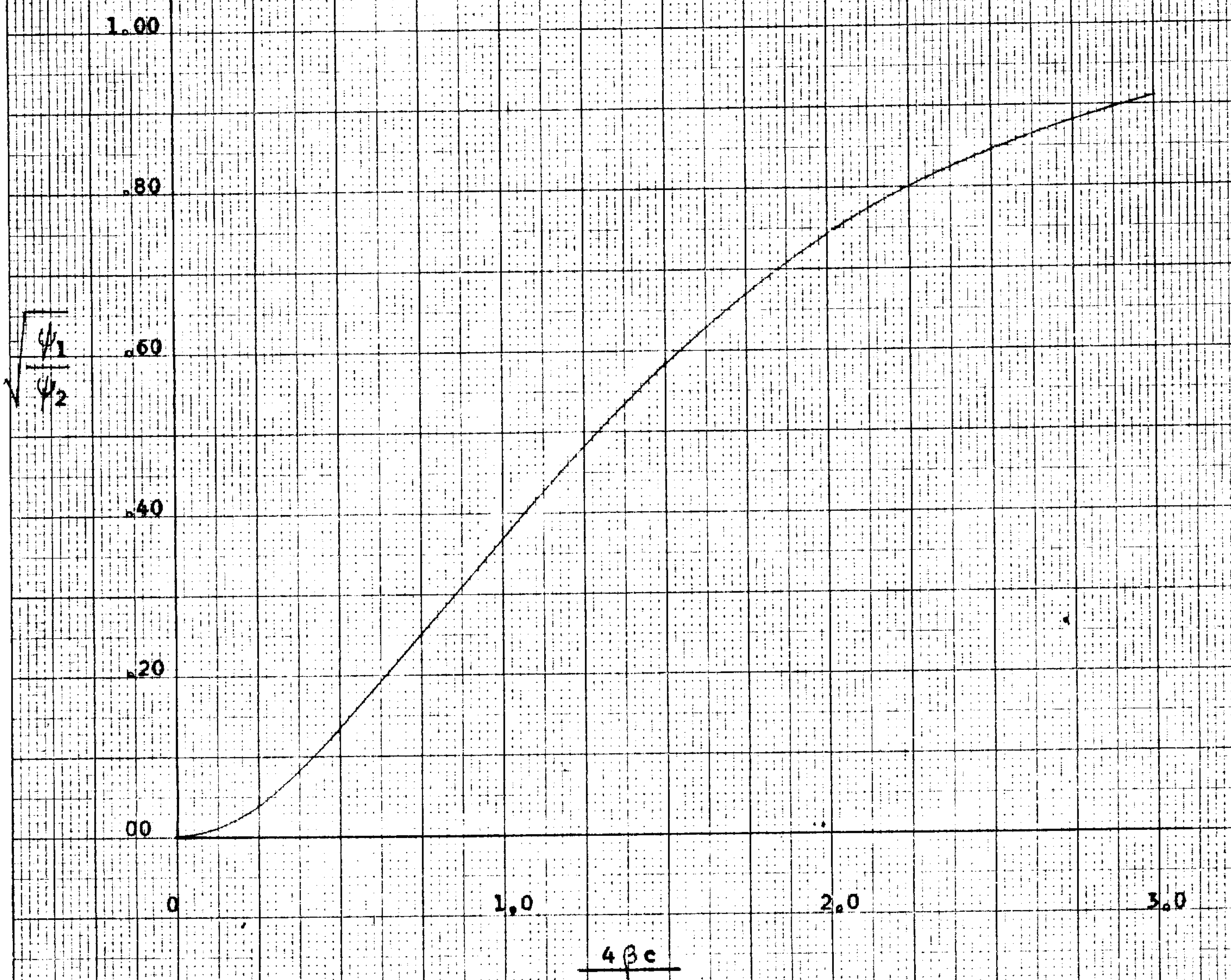


Figure 5: Plot of Optimum Filter Transmission Ratio

Approved For Release 2000/05/10 : CIA-RDP78B04747A003100010043-0

Using the basis for determination of the filter constants laid down in the 9019 study, and lacking suitable high-frequency content transparencies upon which to operate, it was decided to specify the filter for the feasibility tests as follows:

$$a = 64$$

$$\rho = 4\beta c = 1.0$$

To facilitate the construction of the filter so that adequate material would be available on the periphery, the decision was then made to take the maximum filter transmission equal to 50%. By Figure 5, the optimum filter ratio is 0.369. Coupled with the requirement of 50% maximum transmission, the remaining constants are:

$$\psi_2^{1/2} = 0.50$$

$$\psi_1^{1/2} = 0.1845$$

The filter contour is then plotted in Figure 6 to illustrate the general shape.

Contour specification and filter fabrication

Since it would be necessary to specify the contour in rectangular coordinates for purposes of machine-shop fabrication, a transformation of the data was necessary. Incorporating the cited filter constants, the angular relationships were transformed to rectangular through the following equations:

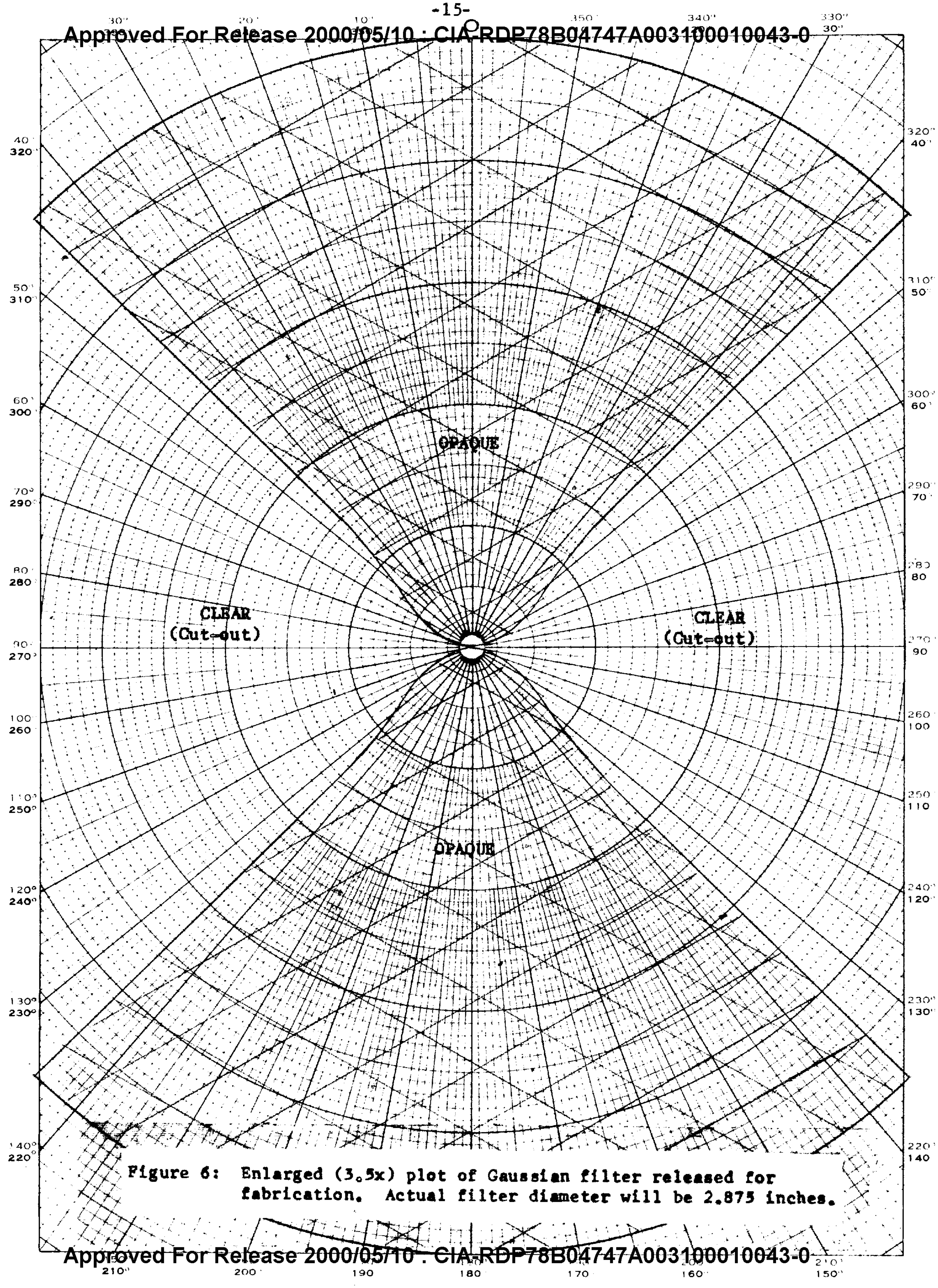


Figure 6: Enlarged (3.5x) plot of Gaussian filter released for fabrication. Actual filter diameter will be 2.875 inches.

$$x = \left(\frac{\sqrt{2}}{2}\right) \bar{r} \left\{\text{Cos } A + \text{Sin } A\right\}$$

$$y = \left(\frac{\sqrt{2}}{2}\right) \bar{r} \left\{\text{Cos } A - \text{Sin } A\right\}$$

$$A = 0.6812\ e^{-30.9716\ r^2} ,$$

$\underline{r}$ now in actual physical units, inches. These points are shown in Table II, out to the region where there is no deviation from the equation y = x.

Considering the difficulty to be expected in mechanical centering, it was decided to make the filter in one piece, and in view of the tolerances involved, to use an electroforming technique for fabrication. Through answers to a request for quotation from outside vendors, it was ascertained that the minimum practical gap between the opaque sections of the filter was 0.003 inches, and that the contour could be held to within 0.001 inches. This necessitated a change in the contour coordinates to accomodate this gap increase. The adapter which was designed to hold the filters for rotation had four set screws located 90° apart which could be brought to bear against the outside rim of the filter and close the gap to any arbitrary setting. Then the contour coordinates were changed slightly so that when screw pressure was applied to the sides, the resultant deformation would closely approximate the correct filter. This allowed the filter to be "opened up" at the center to permit fabrication. The corrected

TABLE II

TABLE OF COORDINATES FOR GAUSSIAN SPATIAL FILTER

The following tabulation of coordinates is for the 1st Quadrant only.
(All dimensions in inches)

x	y	x	y
.000	.0005*	.172	.121
.005	.001	.177	.130
.010	.0015*	.183	.140
.020	.0025*	.188	.149
.030	.004	.199	.168
.040	.006	.210	.186
.049	.008	.221	.203
.059	.011	.233	.220
.069	.014	.245	.236
.078	.018	.258	.252
.087	.023	.271	.267
.096	.028	.284	.281
.105	.034	.298	.296
.113	.041	.312	.311
.121	.048	.326	.325
.128	.056	.354	.3535*
.135	.065	.382	.382
.142	.074	⋮	⋮
.149	.083	In this region,	
.155	.092	x = y	
.161	.102	exactly.	
.166	.111	1.042	1.042

* The values in this region are changing slowly, and rounding-off will give values too much in variance with what is desired. If possible these dimensions should be held.

coordinates are tabulated in Table III. Two such filters were fabricated and used for the feasibility tests.

Feasibility Tests:

Equipment

It was necessary to design and construct a mechanism which would hold the filter in place and rotate it sufficiently fast to obviate flicker and produce the necessary image integration. This device also had to be continuously adjustable in the vertical and horizontal planes, and be capable of adjustment of the filter to place it about the center of rotation.

The device consists of a Servo-Tek 1/20 HP motor controlled through a diode bridge circuit and rheostat, coupled through a timing belt and appropriate sprockets to the filter holder which is mounted in a large-diameter inner bearing race. The outer race is held fixed in a steel frame. The vertical adjustment is accomplished through levelling jack-screws, the horizontal by sliding the base on which the unit is mounted, through application of push-pull screw forces. The motor is capable of speeds up to 5000 RPM. It was determined that the speed necessary to overcome the objectionable flicker would lie between 600 and 2000 RPM, so that the gearing and timing belt combination limits the maximum rate to 2000 RPM.

Initial tests indicated serious vibration problems, and several methods were tried to minimize the effect on the aerial image. Finally, Vibra-Check, a material previously used on the Image Enhancement

TABLE III

TABLE OF COORDINATES FOR GAUSSIAN FILTER (Revised)

The following tabulation of coordinates is for the 1st Quadrant only; the dimensions are in inches.

x	y	x	y
.000	.002	.172	.123
.005	.0025*	.177	.132
.010	.0030	.183	.142
.020	.0040	.188	.151
.030	.006	.199	.170
.040	.008	.210	.188
.049	.010	.221	.204
.059	.013	.233	.221
.069	.016	.245	.237
.078	.020	.258	.253
.087	.025	.271	.268
.096	.030	.284	.282
.105	.036	.298	.296
.113	.043	.312	.311
.121	.050	.326	.325
.128	.058	.354	.3535*
.135	.067	.382	.382
.142	.076		
.149	.085	In this region, x = y exactly	
.155	.094		
.161	.104		
.166	.113	1.042	1.042

* The values in this region are changing slowly, and rounding-off will give values too much in variance with what is desired. If possible, these dimensions should be held.

Viewer to eliminate building vibration, was installed, and the vibrations reduced past the point of affecting the filter evaluation. The Vibra-Check was bonded to both the rotating jig levelling plate and the movable base plate with Pliobond to prevent shifting during the centering and alignment operations.

A photograph of the rotating filter device and the optical equipment with which it was used is shown in Figure 7. The filter shown in the rotating device is a single-unit filter, about which more will be said later.

Filter Alignment

Preparatory to assessing the filtering properties of the rotating profiled slot, it was necessary to insure that it was precisely centered, about the center of rotation. This was accomplished as follows. A diffuse illumination backlighted the rotating filter while a set of achromatic doublets image the filter plane onto a slit of a scanning photometer. The output of the photometer was put onto a moving chart so that a permanent record of results was obtained. This also served as a check on reproducibility and on how well the filter remained aligned.

Initial problems in evenness of the backlight illumination were overcome, and the filter centered through adjustment of the set-screws in the filter adapter. The designed filter, as plotted in Figure 6, was found to be quite difficult to adjust, insofar as adjustments away from the center were required, since the set-screws did not provide this type of correction. Since the filter shape would be retained

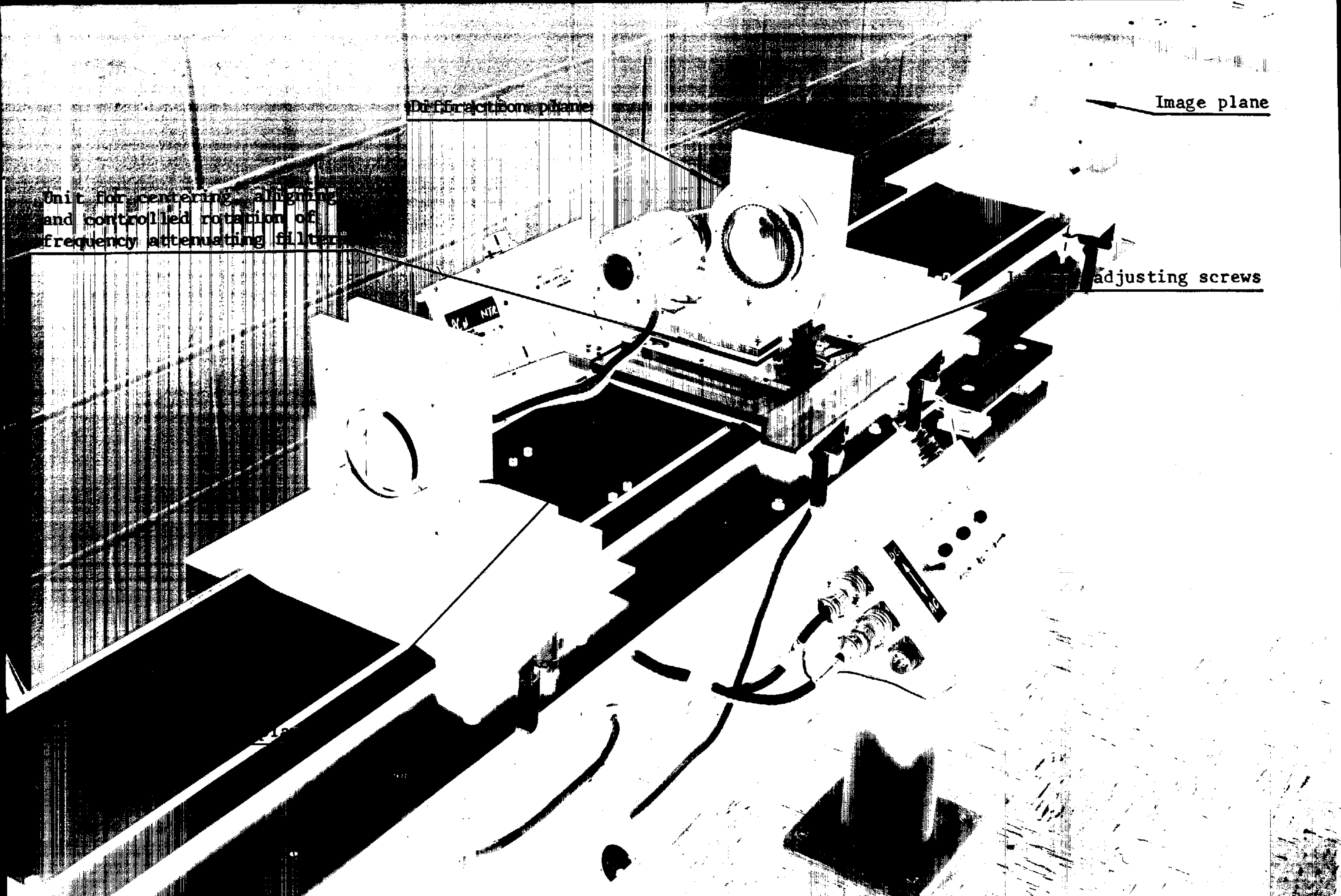


Figure 7: [illegible] of the experimental equipment for testing and evaluation of [illegible] rotating filters, mounted on the Itek Spatial Filtering Test Bench. The bench dimensions and optics are identical to those of the Image Enhancement Viewer. The rotating fixture holds the single-unit filter and is not rotating in the picture.

(although the optimum filter transmission ratio would not obtain) it was decided to eliminate one of the opaque sections to facilitate adjustment. This was found to be more easily centered, although the centering operation was still found to be quite sensitive. Figure 8 is a photograph of two traces produced during these centering tests which are typical of approximately a score necessary to adjust the filter properly. One shows the filter to be slightly outside the center of rotation, the other to be exactly centered. The single-unit filter, while rotated at the same RPM* as the double unit, achieved only half as much beam-cutting, and this is evident on the trace, where the instrument stylus actually follows the "on-off" fluctuations of the photocell. The smooth portion at the center of the trace indicates exact alignment, since there is no "chopping", and hence no stylus jitter.

Filter Evaluation

Once the filter was centered, the incoherent illumination was removed, and the filter placed in the diffraction plane of a linear,

* RPM was measured with a General Radio Type 1531-A Strobotac. Most of the experimental determinations were conducted at or about 1000 RPM, and 1600 RPM was attained with the designed filter without experiencing any resolution loss due to vibration. It was found that after prolonged operation, the bearing grease viscosity dropped somwhat, and RPM increased by approximately 15% over the "cold" or starting speed.

Image trace typical of filter which is rotating around but outside the center of rotation.

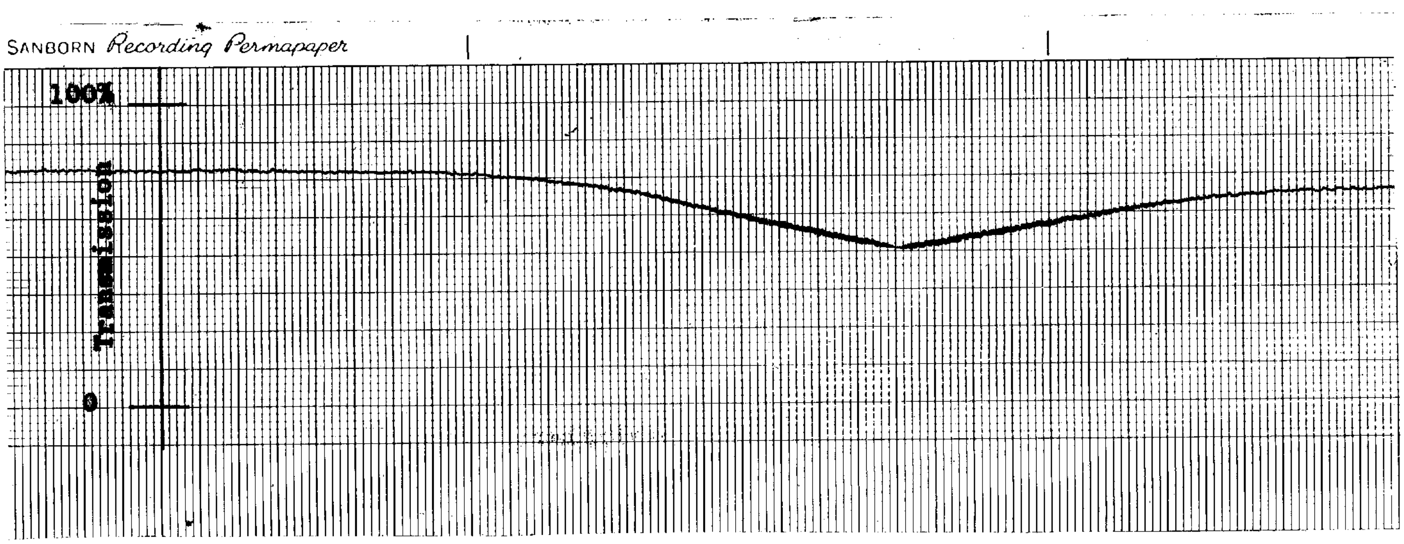


Image trace typical of a filter which is exactly centered, and rotating about the center of rotation.

Figure 8: Portions of typical image traces of a single unit filter made during centering tests. The trace magnifies the image 7.7 times.

coherent optical system identical to the Image Enhancement Viewer. Through use of the levelling jack-screws the lateral screw adjustment, the center of rotation was placed in congruence with the optical axis. This was done by considering the placement of the filter tip at the center of frequency space located precisely with the aid of a diffraction pattern of a Buckbee-Meers bar-target transparency.

The alignment was first carried out visually, then checked by photographing the aerial image of the bar-target while the filter rotated. From previous experience, coupled with the results of the centering tests, it was possible to deduce the degree and direction of misalignment and make the appropriate corrections. Once aligned, the image of bar targets and typical aerial photographs were examined visually and photographically. Having the results of the previous work on the 9019 program, a direct comparison with those results would serve to indicate filtering feasibility.

It was found that none of the filtered images, whether viewed directly or in photographs, were an improvement over the filtered ones, as obtained with the neutral densities produced for the 9019 program. Further, it was ascertained that a general lowering of contrast had resulted without a compensating increase in some other aspect of image quality; as a matter of fact, the photographic and visual images appeared "hazy".

It was decided to examine the image of a bar-target for various static positions of the filter. The filter was placed to point upward, downward, left and right, and the four positions photographed separately. A typical result in shown in Figure 9. It was found that this image type obtained in all four positions; the smearing

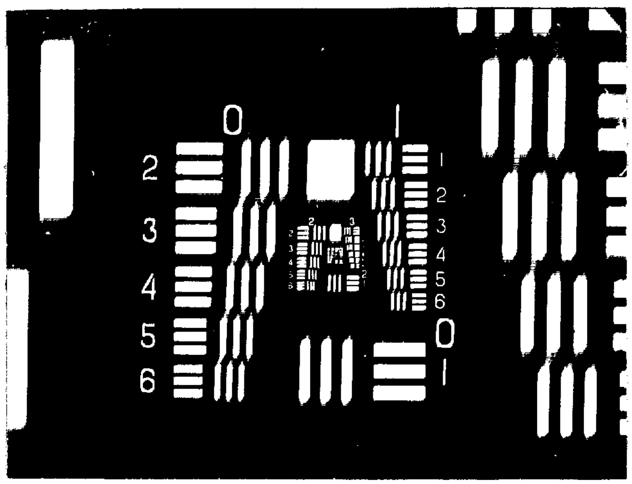


Image with spatial filter stationary and pointing vertically.

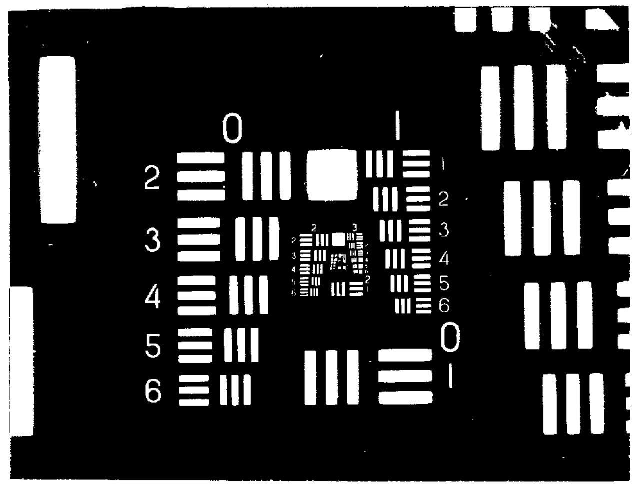
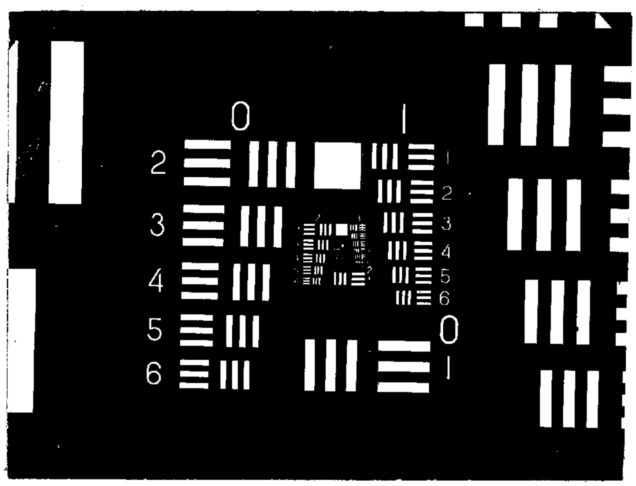


Image with spatial filter rotating at 830 RPM.



Unfiltered image.

Figure 9: Photographs (3x) of the image of a Buckbee-Meers Bar Target, illustrating the effect of low-frequency glint on the aerial image contrast.

or haze always occurs in the direction in which the filter points. Thus, while rotating, the entire image is blanketed by this "smearing" or haze light. Further, as the spatial frequency increases, the effect diminishes, thereby placing the trouble at the center of the system.

The explanation is simple when viewed in this light. Most of the energy is concentrated in the lower frequencies, particularly at 0 lines/mm, or along the optical axis. When the filter is appropriately placed, this light glints from the edge of the filter and specularly reflects over the entire image plane; it predominates at the lower frequencies. The net effect is to add light over the entire image field and thus produce a contrast loss. The effect is not as great at the higher frequencies, and no resolution loss is experienced. However, the over-all effect is to degrade the image. Comparison of the photographs in Figure 9 will illustrate the lack of image quality improvement.

There appears to be no way in which this degradation can be removed or minimized. If the filter is de-centered so that the center of the filter lies outside the center of rotation (which is assumed congruent to the optical axis) filtration will not be accomplished, since the center frequencies must be reduced in comparison with the higher ones. If the de-centering is such that the center of the filter occludes the center of rotation, the filter becomes a sharp cutoff, occluding filter and image tone is lost. The third possibility, that of misaligning the center of rotation with respect to the optical axis, produces effects which are a combination of filtering (occluding) and non-filtering. Since these effects will necessarily be assymetric with respect to frequency space, and since image tone will be partially lost, they do not constitute a solution to the problem.

It therefore is concluded that the method of frequency attenuation using rotating, profiled slots is not feasible, and frequency attenuating filters must be fabricated with the aid of density distributions placed on glass, the difficulties of which have already been discussed in the 9019 final report.

Summary of Feasibility Studies

The feasibility of production of profiled slots for providng a given transmission distribution has been demonstrated, and centering and alignment techniques developed. The evaluation of the filters, however, has divulged a basic incommensurability with the system which renders the rotating, mechanical filters infeasible. This phenomenon is the glinting or reflection of low-frequency image energy onto the image plane which reduces the contrast of the image. No remedy for this effect has been found, and the research on rotating, profiled slots for frequency attenuation has been terminated.

4. Theoretical Studies and Experimental Edge Evaluation

Phase I called for a quantitative evaluation of the sharp cutoff, occluding filters installed in the Image Enhancement Viewer. In anticipation of this, several basic studies were undertaken, the objectives of which were to provide an analytical framework for the evaluation. Among the topics taken into consideration were the analytical descriptions of images of a non-sharp pulse passed through Gaussian and sharp cutoff, occluding filters. Near the end of Phase I, in view of the difficulty of interpreting edge behavior in terms of pulse analysis, the image of a photographic edge passed through sharp cutoff, occluding filters was formulated. This particular analysis required computer aid, and at present is incomplete; i.e., the analytical expressions for aerial image intensity incorporate several tabulated functions and these have not been combined and the image functions plotted and assessed at this writing.

Collaterally, to aid inthe evaluation of the rotating spatial filters, the image of a sharp pulse passed through a Gaussian filter was formulated and used in the interpretation of filtered bar-target images.

A precise assessment of Image Enhancement with the present (improved) equipment was begun. It was determined that there was no way of enhancing an edge with the use of sharp cutoff, occluding filters alone, but that by combining filtered and unfiltered images, there was a technique of image enhancement available. These techniques (exposure addition and transmission multiplication) were described analytically and preliminary verifying experiments carried out. Exposure addition was subjected to very precise experimentation. The extensive experimental data accumulated on exposure addition remains to be analyzed and related to the general enhancement concept. Transmission multiplication was not attempted because present equipment was not capable of overcoming the problem of registration.

Experimental methods of producing a photographic edge of predetermined characteristics were developed, and a series of test edges produced. These edges were later used in the enhancement-through-exposure-addition experiments.

A long step towards the evaluation of the sharp cutoff, occluding filters was taken in Phase I, in combination with a tentative formulation of the enhancement problem. Taken together with the difficulties experienced in the evaluation of the rotating mechanical filters, there was simply insufficient time to complete these studies with the rigor which the problem merits. It is felt that these studies should be extended and finished, to complete our understanding of the enhancement process and to provide a quantitative evaluation of the filters and their use in enhancement.

5. Recommendation for 9043 Project Continuation

Equipment requirements

In view of the fact that Phase I proved the infeasibility of the rotating mechanical filters, Phase II as originally written and set forth in the contract cannot be carried out. However, because of the general usefulness of the equipment, it is felt that with additional modification, its maximum capabilities could be realized.

One of the unofficial complaints about the instrument's use at the contracting agency's facility was the high degree of skill required for its operation and adjustment. Subsequent engineering modifications reduced the need for this skill, but with the latest engineering changes, several modifications could again be usefully applied. As an instance, consider the new angular and linear measurement capability. It is now important to be able to rapidly and positively position the object transparency in the viewing field for purposes of mensuration, and to do this with precision. The present system uses mechanical cables and through sets of bevel and worm gears positions with accuracy, but not very rapidly and very seldom smoothly. Pairs of selsyns can easily be installed in this unit which will permit not only much more smooth and precise changes of object position, but also with a considerably less expenditure of time and energy. This particular modification would also release the object unit from its present location (because of the necessity for staying within the cut-out of the I-beam) and permit separation of the collimating lenses. This not only corrects the optical system to the proper Fraunhofer diffraction mode, but allows auto-collimation in adjustment.

Thus there is a definite need to simplify the operation of the Image Enhancement Viewer and maximize its very useful spatial filtering properties.

Engineering modifications

With the end to making the instrument more accessable to unskilled personnel, and rendering the total operation one of convenience and improved usefulness, the following alternative program is recommended to replace the program determined for Phase II:

1. Re-wire the Source Unit so that the input and output power leads and the additional control wiring pass through an Amphenol connector located on the forward unit plate.

2. Replace the present Object Unit with a new unit incorporating the following features: a) Selsyn positioning of the object vertically and horizontally, a total of two inches travel in both directions, b) separate the collimating lenses in order to operate in the correct Fraunhofer diffraction mode and to facilitate auto-collimation adjustment. The unit will be able to handle carriers for both film and plates.

3. Install two new occluding filters in the filter unit, to be of 0.020 and 0.010 inches in diameter, approximately. This will extend the filter range by a factor of four (4), and should prove very useful on edges of poor gradient characteristics.

4. Replace the three wooden bipods by two steel pedestals which will be anchored permanently at the contracting agency's facility. This will be shock-mounted as per the agency's building requirements. A Photograph of such an installation is shown in Figure 7 of this report.

5. Replace the present control panel by a new unit which is in the form of a wheeled console. This will incorporate all the power supplies and associated switches and transformers. This will place all electrical power and control devices together and will facilitate maintenance and simplify operation.

6. Provide current-regulation to the DC power supply which eliminates the necessity for prolonged and supervised "warm-up" time by a skilled operator.

7. Install necessary cabling for modifications.

8. Carry out minor miscellaneous engineering changes which are not sufficiently important to list here.

9. Metal-finish Phase I unit and all new proposed items compatibly to complete equipment metal-finishing requirements.

10. Prepare an operating and maintenance manual which will bring the equipment up to date and permit full utilization of the latest modifications. The results of enhancement and spatial filtering studies will be incorporated as they apply.

Enhancement Techniques and Evaluation

It is recommended that the analytical evaluation of the sharp cutoff, occluding filters and the formulation of enhancement with their use be completed. These studies will facilitate optimum use of the equipment. Actually, since most of the experimental work has been initiated, the majority of these studies will be concerned with the analysis and interpretation of experimental data, together with certain definitive experiments required to check the conclusions. The results of these, as they apply, will be incorporated in the operating and maintenance manual previously proposed.

Alternate Phase II Schedule

In view of the generally straightforward engineering changes proposed, the original delivery date of the Phase II program can be met. This calls for completion by 31 January 1963, including all hardware, reports, and manuals. Provided the alternative Phase II is approved by 15 September, no additional time is required. A subsequent approval date would necessarily set back the 31 January date.

Alternate Phase II Cost Estimate

Since many of these modifications would have been included in the original Phase II program, and since the relative complexity of the engineering changes is approximately the same, the cost estimate provided with the Phase II program will not require revision or amendment. No increase in contract funding is required.

EXTENSION OF SPATIAL FILTERING DEVELOPMENT FOR IMAGE ENHANCEMENT VIEWER

INTRODUCTORY BACKGROUND:

Itek Corporation Proposal #3326.01, "Extension of Spatial Filtering Development for Image Enhancement Viewer," was submitted on 24 August 1961, and amended on 6 October 1961. The amendment excised several proposed development areas in order to concentrate on the one which appeared to be the most immediately promising. This development was for application of the rotating filter principle proved-out in the previous contract and reported in IL-9019-1, "Design and Construction of Frequency Attenuating Filters," 15 August 1961. The improvement of several of the optical and mechanical aspects of the instrument was also proposed. The proposal was divided into two Phases, the second to be initiated when and if the feasibility of the mechanical, rotating filters was established. Upon award of the contract, work was begun on Phase I.

PRESENT STATUS:

The mechanical and optical improvements of the instrument were carried out successfully, but the mechanical, rotating filters did not prove feasible. The results of the Phase I work was reported on 31 August 1962 in the 9043 Status Report; Phase I, Final Report, and verbally to the contracting agency's technical representatives approximately a month prior to that date. In a series of studies paralleling the instrument modification, attempts were made (both analytically and experimentally) to examine the general problem of image, or more precisely, edge, enhancement. Because of the termination of the effort at the end of Phase I, these studies were not completed, although useful steps had been taken towards a formal statement of enhancement and an evaluation of the significant parameters.

Phase II work was not begun, pending review of the program, in the form of a redirected effort, as outlined in the final report.

PRESENT INSTRUMENTAL REQUIREMENTS:

It has been reasonably well-established that the Image Enhancement Viewer can be a useful tool when used in that type of operation for which it is pre-eminently suited; edge enhancement. The attempts to make continuous-tone spatial filters, while partially successful, have usually foundered on the rock of image quality. Stated otherwise, a successfully operational coherent optical system has too many inherent image-degrading qualities to provide images of equal or higher quality than those obtainable through incoherent illumination with a well-corrected lens. However, the enhancement afforded edges through the use of high-pass occluding filters, and the possibility of linking this operation with the technique of multiple-image printing renders the problem of extreme image quality of something less than primary importance.

The present configuration of the Image Enhancement Viewer is a vast improvement over the original model, the last two modifications having provided the capability of image magnification, precise film and focal plane registration, and significant increase in illumination level. On the other hand, there remain several, additional modifications which could usefully be incorporated to make the instrument more suitable for routine, operational use. These modifications, and the reasons justifying them were listed in Section 5 of the 9043, Phase I final report previously cited. Under the terms of the 9043, Phase II work statement, these modifications cannot be made since they require a redirected effort, as a work statement. The following section therefore details the suggested redirection.

PROPOSED REDIRECTION OF EFFORT:

There are two main areas of effort into which Phase II will be divided; a) Instrument modification, and b) Enhancement studies. These efforts will be made simultaneously, when possible, and the results of the enhancement studies incorporated in the operation and maintenance manual proposed for the equipment. The detailed breakdown follows.

Instrument Modification

1. Re-wire the Source Unit so that the input and output power leads and the additional control wiring pass through an Amphenol connector located on the forward unit plate.
2. Replace the present Object Unit with a new unit incorporating the following features: a) Selsyn positioning of the object vertically and horizontally, a total of two inches travel in both directions, b) separate the collimating lenses in order to operate in the correct Fraunhofer diffraction mode and to facilitate auto-collimation adjustment. The unit will be capable of handling carriers for film and plates. The carriers will be free of strain.
3. Install two new occluding filters in the filter unit, to be of 0.020 and 0.010 inches in diameter (nominal), approximately. This will extend the filter range by a factor of four (4).
4. Replace the three wooden bipods by two steel pedastals, to be anchored permanently at the contracting agency's facility. This will be shock-mounted and vibration-isolated as per the agency's building requirements.

5. Replace the present control panel by a new unit which is in the form of a wheeled console. This will incorporate all the power supplies and associated switches and transformers. It will place all the electrical power and control devices together and facilitate maintenance and simplify operation.
6. Provide current regulation to the DC power supply which eliminates necessity for prolonged and supervised "warm-up" time by skilled operators.
7. Install necessary cabling modifications.
8. Carry out minor miscellaneous engineering changes which will improve the general usefulness of the instrument, but are not sufficiently important to list here.
9. Prepare an operating and maintenance manual which will bring the instrument up to date and permit full utilization of the latest modifications. The results of the enhancement studies will be incorporated as they apply.
10. Metal-finish the instrument to provide protection against humidity, rust, and similar problems.

ENHANCEMENT STUDIES:

To complete the studies of edges and edge enhancement initiated under Phase I, it is proposed that the experimental work continue on edge enhancement through exposure addition and transmission multiplication. This study will examine the four basic enhancement possibilities, and will particularly be concerned with their inclusion in multiple-image printing. It is expected that the results of these studies will provide a final evaluation of the Image Enhancement Viewer usefulness, with a specification of the parametric effect of high-pass occluding spatial filters on enhancement.

PHASE II SCHEDULE

Phase II as outlined above, will be complete six (6) months from date of award. Shipment to contracting agency's establishment will take place subsequent to this period, at his convenience. All manuals, spare parts, etc., will be due and deliverable at that time. The instrument will be assembled, installed, adjusted, and calibrated by an Itek Laboratories representative, at the contracting agency's establishment when delivered, or at a time specified by him.

9043 MONTHLY STATUS LETTER

21 June 1962 - 20 July 1962

ENGINEERING, FABRICATION, AND DEVELOPMENT PROGRESS:

Assembly of the modified viewing equipment has begun, and all major components are at hand. This unit will be assembled and tested without external metal finishing (in terms of anodizing and/or painting), in order that Phase II fabrication can be finished compatibly. The previous report detailed the optical modifications, and gave only a basic design idea for the improved photographic capability. The 70mm format will be accomplished through a Linhof Cine Rollex Back, especially adapted for the present purposes. Exact location of the focal plane with respect to the optical image in the viewing binoculars will be achieved by the insertion and calibrated placement of a microscope (100x) through the format back. A ground-glass screen will permit viewing of the unmagnified image field, and can be easily pushed back out of the way and stored when it is desired to view the aerial image directly.

Frequency space on the Image Enhancement Viewer has been "calibrated" to account for the effect of the glass in the fluid gate. The nominal focal length of the collimator, 622mm, has been shortened to an effective 582mm. This has resulted in an increase of about 6% in the spatial filter sizes listed in the operating and maintenance manual. Subsequent experimental work has accomodated this fact. Phase I modifications will not change this value, since the collimators will not be relocated (as reported previously). It is expected that Phase II modifications will return to the original value.

Difficulties in the procurement of parts, and the natural time delay between order and receipt will delay total assembly, calibration, and test of this modification, as well as the incorporation of the shutter mechanism. All parts and sub-assemblies have quoted delivery dates prior to 31 July, and it is anticipated that these dates will be met. However, it is also estimated that the unit will not be complete and tested before 9 August 1962.

The design of the experimental rotating spatial filter mechanism has been completed, parts purchased and fabricated, and the basic assembly (without the filter) scheduled for 23 July. The rotating device consists of a Servo-Tek 1/20 HP motor controlled through a diode bridge circuit and rheostat, coupled through a timing belt and appropriate sprockets to the filter holder which is mounted in a large-diameter inner bearing race. The outer race is held fixed, with vertical and horizontal adjustments made on the frame to which the outer race is fixed. The unit will be capable of speeds up to 2000 RPM, and could be increased to 5000 RPM with a larger driver sprocket. The motor will be mounted on a plate which is isolated from the optical bench through LORD Multiplane vibration isolaters. Similar isolation of the bearing and filter will be impossible because of the requisite optical alignment. Upon assembly of this unit, test will be carried out to assess the effect of vibration on the aerial image, without filter. Delivery of the filters is scheduled for the latter part of the week of the 22nd, and on the assumption that this will be met, evaluation of the rotating filters should be completed by 31 August, as originally scheduled.

THEORETICAL STUDIES:

The mathematical formulation of a photographic edge was developed, but remains unverified at this writing. Difficulties were encountered in interpreting edge behavior in terms of the pulse studies previously reported. It was felt that an attempt at formulating the edge response should be made, in view of its more specific application and immediate usefulness for evaluating the filters. Simultaneous study of pulse and edge is presently being carried out and experiments planned to further test the results.

It is expected that a preliminary evaluation of the occluding filter will be made and noted in the report due at the end of Phase I. Improvement of the image edge through spatial filtering, exposure addition, and the multiplication of photographic images has been formulated mathematically. Preliminary experimentation verify these results qualitatively; the wait for suitable precision equipment has hampered the extensive experimental work necessary to pin down these findings quantitatively. It is hoped that a useful, quantitative report on these latter theorizings and experiments will be included in the Phase I final report, but present indications are that it will be delayed.

EXPERIMENTAL:

Photographic edges of a precise gradient and transmission end-points have been produced experimentally. These edges have been placed in the linear optical system of the Image Enhancement Viewer and filtered and unfiltered images recorded photographically. The results of these experiments require more time to evaluate, but do indicate the need for further experiments in which the parameters are varied more widely. The techniques have been set up, and the additional experimentation will not require as much time to carry out.

Techniques for "enhancement" by exposure addition have been developed, and several experiments carried out. The basic idea behind this was noted in the last monthly report, indicating three ways of operating on an image. It is known that filtering the spectrum of an edge with a sharp cutoff, occluding filter locates the edge quite precisely, but tends to remove or lower the density difference across it. Except for mensuration possibilities and for purposes of improved delineation, it is of no use in improving or enhancing image perception, per se, in the general manner desired.

Adding exposures produced by an unfiltered image and an image from which the lower spatial frequencies have been removed is a technique of building up the regions of the image which are considered important. Thus, across an edge, it would be useful to retain or improve the density difference and increase the gradient. It is known that edges which are not "sharp" contain only the lower spatial frequency components when subjected to Fourier analysis. The sharper the pulse, (or edge) the higher the spatial frequency content. Thus, there is a definite tie-in of high spatial frequencies and sharpness of edges. In theory, therefore, adding high spatial frequencies to an edge would tend to reinforce those components which contribute to the desired edge characteristic. It is obvious that these higher spatial frequencies must bear some relationship to the original edge in order for them to add constructively.

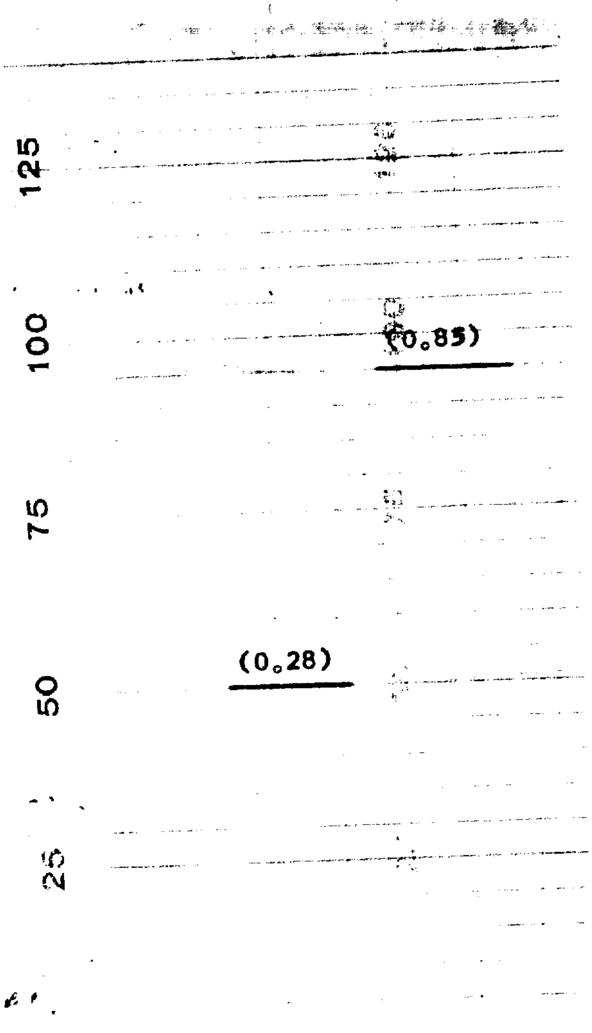
Of the two ways of experimentally realizing this, one was tried; exposure addition. The accompanying Figure shows a typical result. The Figure captions explain the details with sufficient clarity to eliminate their explanation here. The main conclusion to be drawn from the comparison is that while the gradient has not been improved (in fact, degraded quite a bit), the density difference has been increased in the region of the edge. The density difference between the flat areas is exactly the same in both cases. Then the contrast has been improved near the edge, and tonal quality has been preserved. The method of exposure addition tends to produce contrast improvement; the mathematical description of image multiplication indicates that a gradient improvement is more favorable in that case. These experiments require additional refinements before more quantitative results appear, and the method of image multiplication remains to be considered experimentally.

It is not likely that definite, final results will be established by the time of Phase I final report, in view of the extensive experimentation and necessary data analysis still pending.

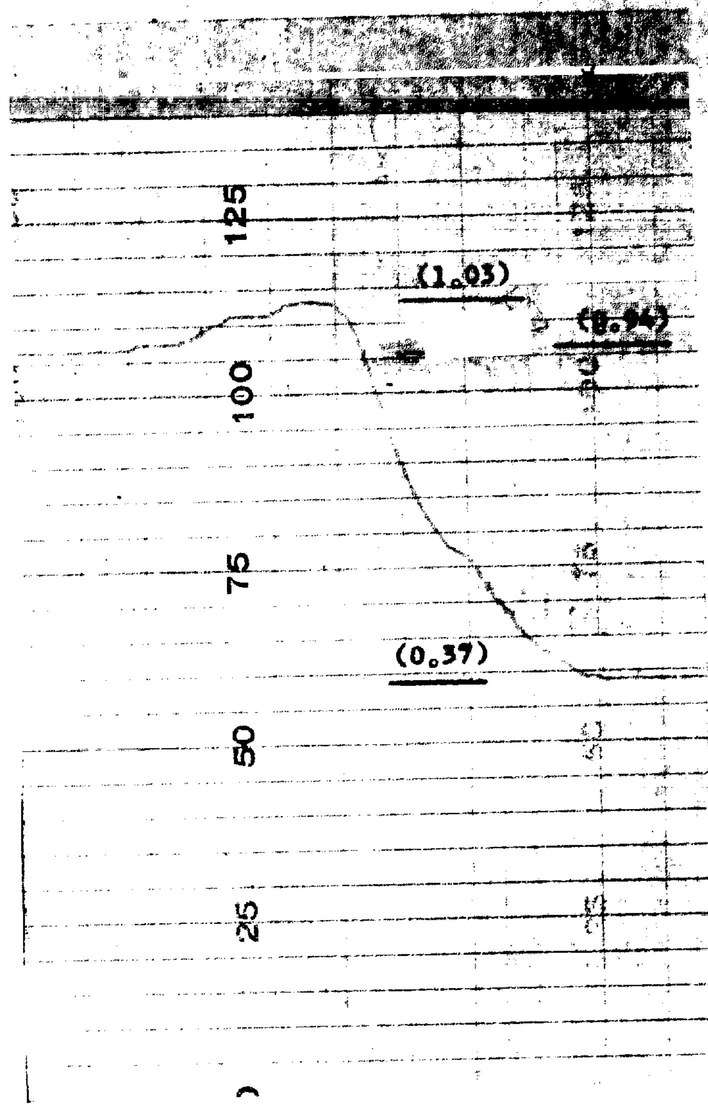
GENERAL SUMMARY:

Progress has been made in all areas of research and engineering. Delivery schedules and fabrication lead-time has forced delay of the completion of the viewer modification until at least the 9th of August. Despite this delay, the evaluation of the rotating filter principle should be accomplished by 31 July. Theoretical developments have been extended to cover the case of edges, but await experimental verification. Experiments on edges and enhancement techniques have been carried out, and while the results have been enlightening, they have not been of sufficient breadth to report definitively.

It is expected that the verbal report on Phase I will be ready for submission by 12 August, and it is suggested that this report be given the week of 12 August or the week of 19 August, whichever is more convenient to the contracting agency. The written report will be delayed by an additional two weeks, to 31 August. However, the verbal report should be sufficient to establish a basis for prosecution of the Phase II developments.



Unfiltered image - exposed for 8 seconds.



Exposure addition in which the original image was exposed for 8 seconds and the filtered image for 90 seconds. The filter occluded all frequencies below 1.5 cycles/mm.

Microdensitometer traces of the photographic images of an edge, showing the effect of adding a spatially filtered image to the original image, in exposure. Chart scales have been converted to density where applicable, and the density values placed in parentheses.

Approved For Release 2000/05/10 : CIA-RDP78B04747A003100010043-0

COR-1990
COPY 1 OF 3

9043 Monthly Status Report

Report #2 for period 21 May 1962 - 20 June 1962

INTRODUCTION:

The previous Monthly Status Report outlined the program which was to be carried out in prosecution of the subject contract. It reported the initiation of work in various sub-tasks. This present report will detail the progress to date and indicate the steps to be taken during the remainder of the Phase I period.

For internal accounting purposes, the sub-tasks reported in the previous Monthly Report have been changed as follows: All sub-tasks of Phase I are charged to 9043.01; all sub-tasks of Phase II (not yet outlined) are charged to 9043.02. No further detailed task breakdown will be made.

During this present report period, a request was placed with the contracting agency for obtaining sample photographic transparencies upon whose characteristics the decision of spatial filter width could be based. * Since no answer was received, and because the time for fabrication was critical, a filter was chosen which would be suitable for operating on the spectrum of transparencies generally obtainable at this facility. It is to be noted that the frequency content of these transparencies will be considerably lower than in those which the contracting agency plans to consider, and, in the qualitative demonstration of enhancement called for at the end of Phase I, will not be representative of the material the contracting agency desires to

* It was alternatively suggested that in lieu of the actual transparencies, a photograph of their power spectrum would suffice. This could be accomplished at the contractor's facilities or at a place designated by the contracting agency, in a manner which would prevent the photographer's subjection to classified material.

enhance. However, it is hoped that the security problem may be overcome by the time Phase II filter decisions are required, and that a set of filters suitable to the contracting agency's photographic transparency quality may be fabricated.

ENGINEERING, FABRICATION, AND DEVELOPMENT PROGRESS;

The design of the modification to the viewing equipment has been completed. All optical parts have been purchased and in storage at this facility, with the exception of a front-surface mirror presently being figured in the Itek Optical Shop. This mirror will be completed and aluminized by 16 July 1962, ready for installation. The structure and associated parts have been released to the shop for fabrication, and it is expected that fabrication, installation and calibration will be completed by 31 July.

The enclosed design sketch shows the modification in detail, and indicates the type of equipment which will be used. The B & L Tri-ocular, will have Zoom capabilities from 5 - 25; due to the limitations inherent in the optical elements, it will not be possible to consider Zoom from 1 - 25 as originally intended. However, in view of the fact that details of interest will be viewed at approximately 4x, this provides an intitial magnification of details at 20 lines/mm "fine detail" on average presently available transparencies, "medium detail" on higher grade materials.

Present plans do not call for rearrangement of the collimators, as discussed in item 2 of sub-task 9043.01 in the previous report. Because of the necessary cut-outs in the 8-foot channel iron, insufficient longitudinal adjustment exists to accomplish this properly. This change will probably be effected in Phase II when the bench cut-outs will have been rendered unnecessary. Because of the presence of the glass in the fluid gate, frequency space will be out of calibration with the theoretical filter sizes due to the shortening of the collimator focal length. This is a small deviation, and its effect minor.

However, using materials of known frequencies, this coordinate plane will be calibrated and the resultant changes incorporated in the final test results.

The shutter replacement, discussed in item 3 of sub-task 9043.01 has been designed, and the materials ordered. The new shutter will be self-cocking, and will have its speeds adjustable through a lever which will protrude from the forward side-wall of the Source Unit. This will allow continous adjustment of the shutter speeds and a less-destructive means of tripping. It will require operation from the Source Unit, but this will be carried out through the control panel when Phase II modifications are incorporated. This shutter, and its associated mechanisms will be installed by 31 July 1962.

Design of the rotating spatial filter mechanism has been initiated. It is planned to rotate the filter within a range of 600 to 2000 revolutions per minute, adjustable at the discretion of the operator. This provides a means for overcoming vibrations due to imbalance in the rotating mechanism by allowing a speed range sufficient to pass over any resonance point. The basic design has been completed, and the components under purchase requisition. Detail shop drawings will be released for fabrication by the end of the month.

The filter slot contour has been chosen (See next section) and the slot profiled prior to release to outside vendor for fabrication. The accuracy with which these slots must be cut and centered requires pantographic techniques, working from a 10x enlarged die. The present facilities do not posess such equipment, and it will be necessary to sub-contract the part. Present information indicates that the slot can be cut and suitably finished within three weeks of receipt of authorization. It is expected that the purchase requsitions covering this will be issued by 22 June 1962.

Lateral and vertical adjustment of the rotating slot will be effected by screw adjustment. Continuous, electrical methods of centering were considered, but in view of the present expectation that little dynamic adjustment will be required during normal operation, they were eschewed in favor of the mechanical means. However, since the vibration problem is as yet an unknown factor (its presence could result in the need for more continuous adjustment), the final decision on adjustment techniques must await the feasibility tests scheduled for the latter part of Phase I - the next report period.

THEORETCIAL STUDIES:

The mathematics necessary for the specification of filter slot contour, and the filtered effect on an optical image have been developed, using the principles laid down in the 9019 final report. Using a Gaussian filter whose effective normalized cross-section in the plane of diffraction is given by,

$$G(\bar{r}) = \sqrt{T_2} - \left(\sqrt{T_2} - \sqrt{T_1} \right) e^{-\alpha \bar{r}^2}$$

where

T_2 = maximum transmission

T_1 = minimum transmission

$\bar{r}$ = r/r max. , r = radius

a contour suitable for the feasibility tests has been determined. The choice of the filter constant, α , was based on observations made on the 9019 work, coupled with the size of the amplitude spectrum on which it is expected to operate.
For the filter to be fabricated, the following constants were chosen:

α = 64

T_2 = 0.25

T_1/T_2 = 0.136

A graph of the filter is shown in the accompanying figure. It bears a similarity to those of the 9019 final report, except that for mechanical reasons, the slot has been given lateral symmetry. These subtasks therefore may be considered completed with the specification of the filter constants, and the analytical expression for the Gaussian spatial filter.

SHARP CUTOFF FILTERS AND NON-SHARP PULSES:

The analysis of non-sharp, Gaussian pulses passed through high-pass occluding filters has also been completed. This treats the theoretical imaging of a specific, non-sharp pulse as filtered by the kind of spatial filters presently installed in the Image Enhancement Viewer. The end result of these studies is the analytical specification of filtered images in order to obviate trial-and-error filter evaluation and usage. This constitues one step in the description of Image Enhancement by use of occluding filters, and is a formulation sufficient for its experimental testing.

For reasons of convenience, a Gaussian pulse shape has been chosen. There is no a priori reason for its choice, other than the fact that such a shape fits a wide variety of experimental edges and pulses. Pulses have been chosen in preference to edges, because of the mathematical symmetry. In experimental practice, edges are of more fundamental interest, but the relation between the two are close; that is, experimental images of edges may be interpreted in terms of what is known about pulses whose edge characteristics are similar. In the mathematical analysis, the significant parameter is the product of filter cutoff frequency and pulse variance. This latter quantity is a measure of the width of the input pulse. The effects of varying this quantity are shown in the accompanying figure, where the parameter varies from 1/4 to 2. The unfiltered pulse results from the case where the filter cutoff falls to zero, equivalent to an image without filtering (and also without bias). These plots have been normalized so that the area under the curves is equal. This is equivalent to demanding that all images contain the same total energy. Without this, proper comparison could not be effected.

The Figure shows that for low values of the parameter, the pulse height has been increased, the mean-squared image slope increased, and the intersection with the x-axis has moved toward the origin. As the parameter increases, the height decreases, and while the trends pointed out for lower values continue in the same manner, there is a noticeable distortion of the original pulse into a series of connected "pulses". This is the ringing resulting from sharp-cutoff, occluding filtering and is commonly encountered in optical systems of this type. Thus, in a qualitative way, the theoretical image intensity follows that experimentally found with high-pass, occluding filtering.

These investigations must be verified by experiment to ascertain their validity. The qualitative reassurance previously discussed does not constitute sufficient proof. These experiments are described in a subsequent section of this report.

PRELIMINARY CONSIDERATIONS OF IMAGE ENHANCEMENT:

One of the major aims of this current study is the description of enhancement and a quantitative evaluation of spatial filtering with sharp cutoff, occluding filters. This problem has existed for quite some time, but, with the inadequate understanding of enhancement, has lacked a fundamental basis upon which to construct an evaluative approach. Probably one of the most talked about and least understood descriptors in present-day usage is, "enhancement". This means many things to many people, and has yet to be used without ambiguity. Experience gained over the studies of 9019 and in connection with the current program indicates there is no one parameter which adequately represents enhancement. Consider the several factors which could possibly enter into such an argument. Generally, it is convenient to increase the contrast of details within a transparency. This can be done with high-pass occluding filters, as shown in the accompanying figure on pulse images. However, in increasing the contrast of a given pulse, an extra ringing image has been introduced. Thus, a mere contrast increase is not the answer, since other factors of the detail information can suffer degredation. Another consideration is that of the instantaneous drop-off between contiguous density regions, or edge gradient. Reference to the cited figure shows that the gradient can be improved but the other image characteristics completely lost. While steepening the gradient is useful, it therefore must be tempered with other considerations. A further consideration is the location of the point where the first image intensity minimum occurs. As this moves toward the origin, the pulse may be considered to be "sharpened" and the edge more readily defined. However, the closer to the origin, in general, the more distorted is the actual pulse shape - ringing destroys the precise rendering of detail.

From these generalizations, it can be seen that image enhancement is not merely an increase in contrast or the steepening of an edge gradient, or the narrowing of the "half-power point". Its objective formulation must necessarily be a com pound of the several factors in a way which maximizes the gains of each, but minimizes the resultant less of information or the injection of false information. To further complicate the problem, it also must necessarily be related to the subjective qualities photo-interpreters consider vital for improving conditions for perception. This final consideration is the most difficult to account for, inasmuch as the process of perception is a quite personal thing and therefore varies widely. The restriction of objective considerations only is placed on the formulation of enhancement for these studies.

In view of the ambiguities present in the problem, it will probably not be possible to specify, a priori, an objective definition of enhancement which encompasses all the quantities previously outlined. Through careful experiment, it will be possible to consider the variation of a given image quality in parametric relation to the others. From such tests, it is hoped, sufficient data will be developed so that deductions on the meaning and form of enhancement may be established. Of course, these tests are not "starting from scratch." The major objective factors which affect image quality are reasonably well-known, albeit mostly in a qualitative manner. For instance, the specification that "enhancement of an edge consists of maximizing the mean-squared gradient, while keeping a fixed percentage of the image energy within the area bounded by the first image intensity minimum," is a useful working hypothesis, while its quantitative variation as a function of spatial filter cutoff frequency is not yet established.

The evaluation of the occluding filters presently installed in the Image Enhancement Viewer will proceed with respect to this preliminary consideration of enhancement. There are three distinct possibilities open to consideration:

1) spatial filtering with high-pass, occluding filters,

2) addition of filtered and non-filtered image intensities as photographic exposure with a subsequent printing, and

3) the multiplication of filtered and non-filtered photographic images through superposition of two negative materials, with a subsequent printing.

The mathematical formulation of these three possibilities has been carried out, and will be subjected to experimental testing during the next report period. It is difficult at this time to state definitely which of the three is the best technique for enhancement. The latter two methods employ photographic images and are not suitable for "dynamic" viewing of an object transparency under "enhancement", as is the first. However, they do possess qualities which recommend their application; photographic amplification and rectification techniques, permanent record of results, to name two. The major disadvantages are the time element and the necessity for high operator-skill. It is expected that a series of well-controlled experiments will divulge the relative virtues of these techniques, and provide a measure of enhancement based on the use of sharp cutoff, occluding spatial filters.

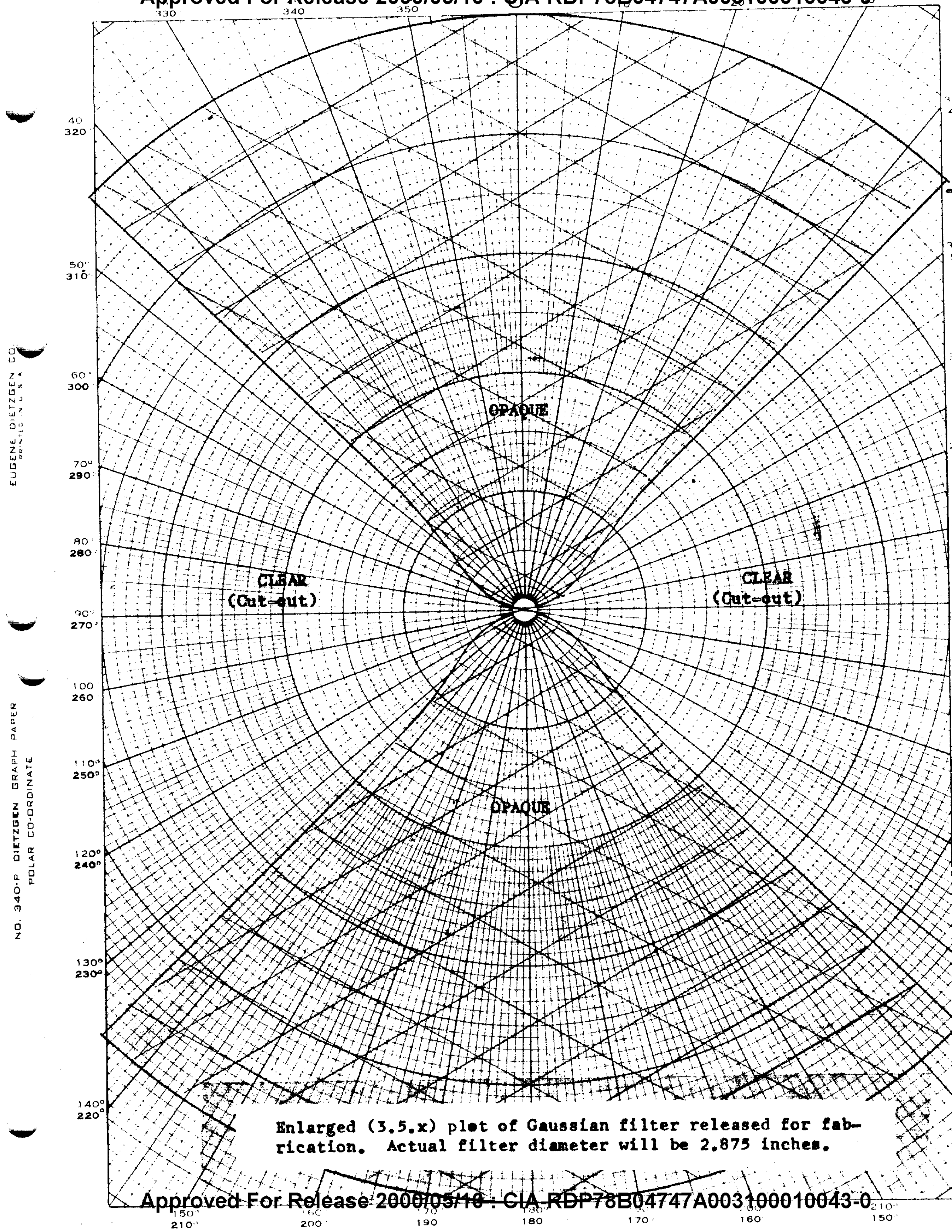
EXPERIMENTAL:

The experiments to consider enhancement and non-sharp pulse imagery have been initiated. The problem is the theoretical designation and experimental realization of photographic edges of known gradients. These edges must be constructed in a manner which permits parametric variation of the primary quantities; gradient, optical transmission levels. By holding one constant, the other may be varied, as the effect of spatial filtering is evaluated and related to the general problem of enhancement. Since these test edges should bear a direct relationship to materials and practices which will be ordinarily encountered, they are being made through the use of optical systems (in contrast to, say, edge degredation through the use of a pinhole camera, or smearing of a knife edge exposure). Thus, the lens spread function as well as the transfer characteristics of the photographic material are being used to provide "real" edges.

Techniques have been developed which provide photographic edges of specific edge gradient, for various levels of optical transmission. These edges will be filtered in the Image Enhancement Viewer and the images, both visual and photographic, studied in relation to the predicted behavior (as shown on the accompanying Figure) and in terms of the quantities which reflect the current thinking on enhancement. These studies will probably carry to the limit of the Phase I time-schedule, in view of the extensive and careful experimentation necessary.

GENERAL SUMMARY:

Progress is reported in all sub-tasks of the 9043.01 Program. Viewer Modifications have been designed, parts purchased, shop drawings released for fabrication. Rotation device for the filters has been designed, parts purchased, detail drawings being readied for release. Theoretical studies have been carried out which have furnished a test filter slot contour for purpose of establishing a fabrication technique. Mechanical assembly and test of the Viewer Modifications will be complete by 31 July. Establishment of the feasibility of the filter rotation principle, depending on the assembly and adjustment of the purchased and fabricated parts, will probably be delayed for a week or two after the close of the nominal schedule for Phase I. This estimate is made in view of the generally long lead time required for fabrication and purchase of parts. It will not affect the over-all schedule, since Phase II time can easily absorb the several extra weeks. Progress has been made on the understanding of enhancement and its formulation in objective terms. Tests are planned which will test the several factors relating to enhancement, using the non-sharp pulse model and the sharp-cutoff occluding filters presently installed in the Image Enhancement Viewer. It is anticipated that these experiments will be completed by the end of Phase I and should culminate in a more definitive meaning for Image Enhancement.



Enlarged (3.5.x) plot of Gaussian filter released for fabrication. Actual filter diameter will be 2.875 inches.

Approved For Release 2000/05/10 : CIA-RDP78B04747A003100010043-0

DPD 3449-62
COPY 3 OF 3

9043 Monthly Status Report

Report #1 for period 1 May 1962 - 20 May 1962

Itek
BB-425, T.O. #4

INTRODUCTION:

This period was spent in setting up a schedule for Phase I work, obtaining personnel and assigning them specific tasks, and in making the purchases of optical and associated equipment related to the modification to the viewing end of the Image Enhancement Viewer. Work on the theoretical studies was initiated.

The project was assigned an Itek number 9043 and the program broken into four sub-tasks. This breakdown is as follows.

EQUIPMENT MODIFICATION 9043.01:

1. Design, construct, assemble, and test necessary modifications to the Image Enhancement Viewer which incorporated the following:

   a. Tri-ocular microscope, with variable (ZOOM) magnification, incorporating a 35mm camera to photograph the magnified image;

   b. Change the present format to 70mm, using a standard 70mm magazine and transport mechanism;

   c. Provide for mensuration of the aerial image through the use of a Filar eyepiece, and allow for angular measurements through calibrated rotation of the tri-ocular microscope mounting;

   d. Provide a focussing adjustment for the 70mm format, to allow finer adjustment of the focal plane and a more critical adjustment of the system focus;

   e. Provide a screen (ground glass or equivalent) for viewing the unmagnified image;

   f. Provide the proper amount of front surface mirrors of the requisite quality to fold or deflect the images so that the requirements of items <u>a</u> through <u>e</u> above, may be made compatible.

2. Rearrange the collimating lenses (presently mounted together and in front of object space) to provide an exact scale in frequency space and to facilitate instrumental adjustment by auto-collimation. This is to be carried out only if sufficient space on the bench is available (or can be accomodated in the folding or deflection implicit in Item 1, above). If not deemed feasible because of inadequate length, frequency space must be calibrated with standard objects and so recorded in the manual due at the conclusion of Phase II.
3. Repair, replace, or modify the shutter arrangement in the Source unit of the Viewer. Present location and operation requires manual adjustment of shutter speed and is not conducive to normal shutter life.
4. (Optional, in anticipation of PhaseII). Consider (sketch out if feasible) modifications to produce semi-automatic power supply adjustment for operational simplification of the d.c. Power Supply.

THEORETICAL STUDIES 9043.02:

1. Correct mathematical filter descriptions outlined in the 9019 final report as they incorporate amplitude weighting of the filter cross-sections. Recompute the relevant functions and replot the Figures.
2. Develop the necessary mathematics for the mechanical rotating, attenuating filters, following the principles outlined in the 9019 final report.
3. Using a Gaussian model, provide typical filter contours for purposes of developing mechanical techniques for their construction; to be used in conjunction with the engineering developments of the rotating techniques.

4. Complete the analysis of non-sharp pulses (Gaussian edges) passed through occluding filters, for use in evaluating the performance of these filter types. Derive the mathematical expressions describing how these filters may be used to enhance photographic edges (through two photographic processes) and using a suitable criterion for evaluation, indicate their specific usefulness in operating on the frequency content and general edge contrast of aerial images. These results will be tested in experiments under 9043.04.

ENGINEERING DEVELOPMENT 9043.03:

1. Design and construct a mechanism or mechanical assembly for achieving frequency attenuation by means of a contoured slot rotating in frequency space about the optical axis. The following will be considered and/or incorporated:

    a. Rotation of a circular disc containing the contoured slot, utilizing rim-drive or equivalent.

    b. Positioning mechanism which is adjustable in two-coordinate positions (x and y) perpendicular to the optical axis. Both manual and electrical (selsyn) centering adjustments should be considered.

    c. Provide a means for reasonably rapid and simple filter change.

    d. Consider, test, and remove variations due to vibration or transient shock, incorporating isolators or shock mounts as required.

    e. Develop methods for cutting out or forming the precise slot contours provided by the mathematical analysis. This is primarily a shop problem.

2. Test the filters and rotating filter mechanism to establish general feasibility, paying specific attention to the problem of centering stability and introduction of vibration.

3. Draw up general system specifications for Phase II program.

EXPERIMENTAL TESTING 9043.04:

1. Perform tests of spatial filtering with occluding filters on objects of known edge gradient, for the precise evaluation of occluding filters and their use in image enhancement. It will be necessary to construct such test edges, the physical constants of which will be given by the mathematical studies in conjunction with studies on real photographic edges.

2. Using the test objects above, demonstrate the qualitative enhancement resulting from the use of the new mechanical frequency attenuating filters.

The next report period will cover 20 May - 20 June. It is expected that most of the the theoretical studies will be comnlete by this time, as well as the design of the viewing modifications. Work on the engineering development of the mechanical frequency attenuating filters will be initiated, and the basic equipment such as motors, selsyns, micrometers, etc. will be purchased. Preliminary evaluation of the occluding filters should begin during this period.